1996

R290 as a Substitute of R502 and R22 in Commercial Refrigeration and Air Conditioning

G. Lampugnani
Embraco Aspera-Product Engineering

M. Zgliczynski
Embraco Aspera-Product Engineering

R290 AS A SUBSTITUTE OF R502 AND R22 IN COMMERCIAL REFRIGERATION AND AIR CONDITIONING

Giovanni Lampugnani, Marek Zgliczynski
Embraco Aspera-Product Engineering
Via Buttigliera 6, 10020 Riva presso Chieri (TO) - Italia

ABSTRACT

The research to find refrigerants suitable as candidates to replace R22 and R502, has to considerate not only the thermodynamic characteristics of the alternatives, but also its impact on the earth ecosystem; on the basis of the above considerations and considering the updated European standards on the allowed refrigerants, the impact of the use of propane (R290) in hermetic compressors for air conditioning and commercial refrigeration has been analyzed.
The performances of R290 in comparison with R22 are presented, from the theoretical as well as from experimental point of view. The influence of R290 on compressor reliability has been also evaluated analyzing the bearing load and considering both the materials compatibility and the oil solubility; the lower operating temperature has a positive impact on compressor reliability. Some considerations on safety are also presented.

INTRODUCTION

The growing concern about the earth climate has been reflected in the Montreal Protocol and its revisions, forcing the ban of CFCs. The attention is now focused on HCFCs; it is expected that the ninth revision of the protocol (scheduled in 1997 - Montreal), will strength the phase-out of the R 22 and other HCFCs. The increasing pressure, especially in Europe, to speed-up the HCFCs substitution, forced the research to find suitable candidates to replace R 22; it is desirable that the " optimum candidate " could be also a valid R 502 alternative.

Due to increasing importance assumed by the greenhouse effect, not only the ODP, but also the GWP has to be considered as a primary characteristic to be evaluated while selecting a potential replacement for the R 22 and R502. In table 1, the " climate affecting properties" of R 22, R502 and some major candidates to their replacement are reported.

Table 1: ODP and GWP values

Refrigerant	ODP	GWP rel. CO_2		
		20 years	100 years	500 years
R 502	0.283	5273	5591	6910
R 22	0.05	4300	1700	520
R404A	0	4948	3748	1333
R407B	0	4200	2558	872
R407C	0	3330	1609	535
R507	0	5000	3800	1350
R410A	0	3300	1890	640
R290	0	3	3	3

The data in the above table indicate that, from the "earth climate" point of view, the most interesting candidate to replace R 22 and R 502 is R 290 (propane), not widely considered until now for safety reason only. The last revision of BS4434, DIN 7003, IEC 335-2-24 as well as the pr EN378 allow, under specified conditions, the use of flammable refrigerants.

Other strong advantages of propane are the common availability, its low cost and the compatibility with mineral and alkylbenzene oils, together with the materials used in the hermetic motorcompressors and in the refrigeration systems. The unique and most undesirable characteristic is its flammability.

PERFORMANCES COMPARISON

Theoretical comparison

Some physical properties of the refrigerants listed in table 1, are reported in table 2.

Table 2: physical properties of refrigerants

REFRIGERANT	MW [kg/kmole]	NBP [°C]	Crit. Temp. [°C]	Crit.Press [MPa].	L.E.L. [% vol.]	U.E.L. [% vol.]
R 502	111.6	-45.4	82.1	4.98	-	-
R22	86.5	-40.8	96	4.07	-	-
R404A	57.6	-46.3	72	3.74	-	-
R407B	102.9	-47.4	76	4.16	-	-
R407C	86.2	-43.6	86.7	4.62	-	-
R507	98.9	-46.7	70.9	3.79	-	-
R410A	72.6	-52.7	72.5	4.95	-	-
R290	44.1	-42.1	96.8	4.25	2.1	9.5

R290 has the highest critical temperature; in general, the highest is the critical temperature, the highest is the latent heat of vaporization, that normally means higher efficiency. As negative point we have a lower operating pressure, with consequent lower vapor density that will be reflected in a lower volumetric capacity. As a consequence a larger displacement could be required for the compressor.

The performance comparison of the different refrigerants is based on an ideal refrigeration cycle, assuming isentropic compression and ideal compressor (i.e. efficiency = 1). the cycle performance were evaluated considering L.B.P. conditions for R502 comparison and H.B.P. conditions for R22 comparison. The NIST Standard Reference Data Base Refprop 4.0 was used to calculate the thermodynamic properties of the refrigerants. The operating temperatures are summarized in table 3.

Table 3: operating conditions

Cycle	Evap.Temp. [°C]	Cond.Temp. [°C]	Suct.Temp. [°C]	Subcooling [K]
L.B.P.	-40	40	32.2	0
	-23.3	54.4	32.2	0
	-15	60	32.2	0
H.B.P.	-15	54.4	20	8.3
	0	54.4	20	8.3
	7.2	54.4	20	8.3

The graphical comparison of the most significant parameters are reported in fig. 1, 2, 3, 4, 5, 6

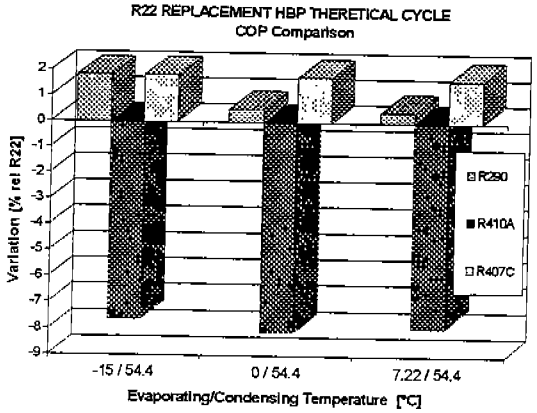

Fig 1

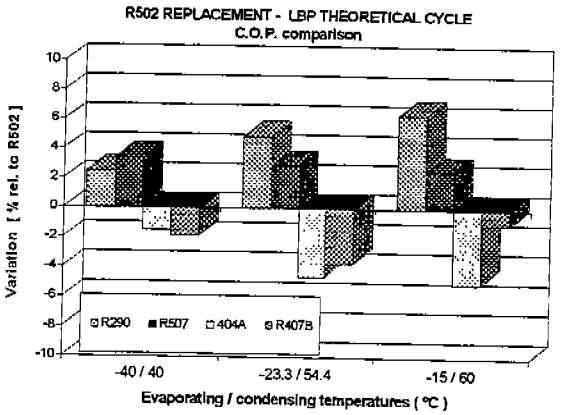

Fig 2

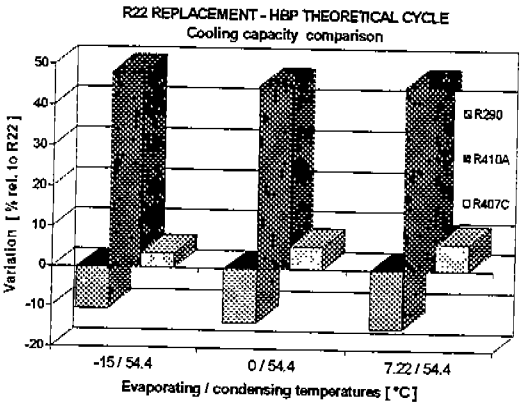

Fig 3

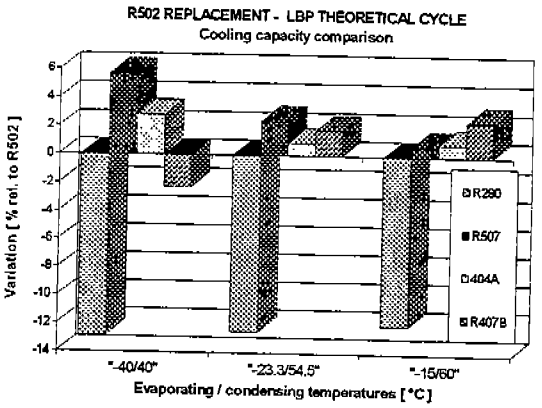

Fig 4

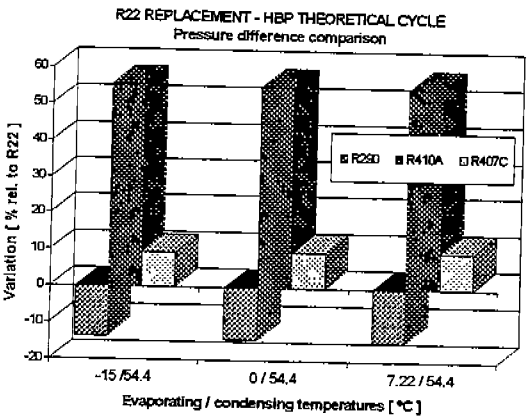

Fig 5

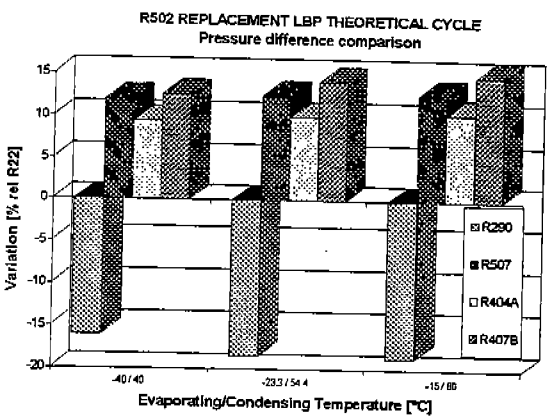

Fig 6

The main characteristics of propane, in comparison with R22 and R502, are summarized in table 4.

Table 4: cycle comparison

	R290 Vs R22 HBP	R290 Vs R502 LBP
Suction Pressure	- 6%	-15%
Discharge Pressure	- 12%	-18%
Pressure Difference	- 15%	-19%
Pressure Ratio	- 7%	-4%
Discharge Temperature	-16 K	-6 K
Volumetric Capacity	- 14%	-13%
COP	+0.5%	+5%

As additional comments, we can say that the lower pressure difference means a lower load on the bearings with positive impact on compressor reliability. The lower pressure ratio, mainly in comparison with R22, in conjunction the lower politropic index, will be reflected in a higher compressor volumetric efficiency. the lower discharge temperature has a positive impact both on compressor reliability and performances. From the mentioned considerations, the capacity penalty expected by the use of propane will be lower, as well as will be higher the COP gain.

Experimental comparison

An experimental program has been set to compare the performances of hermetic compressors operating with R290 and R22 on a calorimeter and on appliances. The measurements were performed on two models used in air conditioning and dehumidifier appliances. The first model has a rated capacity of 1800 W; the second one is 760 W rated capacity. The calorimeter results, expressed in variation in comparison with R22, are reported in fig. 7. They represent the average of the performances of the two models; the difference (relative to R22) between the models ranges within 2.5%.

Calorimeter tests results

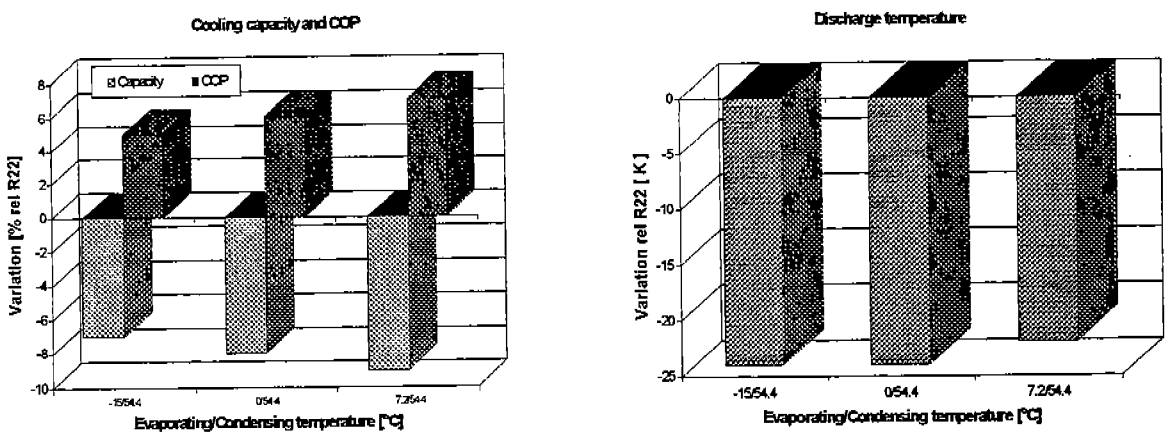

Fig 7

The same comparison was performed on the appliances. Both the air conditioner and the dehumidifier were tested with R22 and after, without modify the systems, charged with R290. According to what we expected, the new charge was about the 50 % of the original. The appliances were tested according ISO 859 for air conditioner and AHAM for dehumidifier. The performances test results are in fig 8.

Appliances tests results

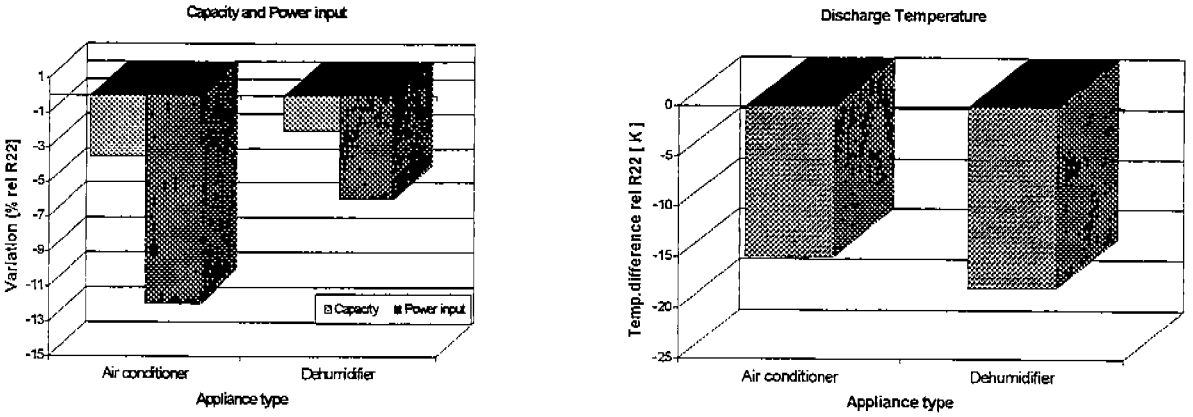

Fig 8

The experimental results show that the behaviour of propane is even better if compared to the theoretical cycle; from the thermodynamical point of view the R290 is an excellent candidate to R22 replacement.

RELIABILITY

The compatibility of R290 with the materials used in the hermetic motorcompressors is well known, and negative surprise were not expected. A series of sealed tube tests were carried out according ASHRAE D97. The behavior of propane with mineral oil and the materials used in the compressors was the same of R600a.

According to the pressure data reported in table 2, the reliability of the compressor would not be affected in negative way. A series of life tests were performed, mainly to verify the behavior of the mineral oil/propane combination in the lubrication of the mechanism. The analysis of the compressors after life tests showed the very good behavior of the mechanism and the valves plates in comparison with R22.

SAFETY CONSIDERATIONS

The only negative characteristic, typical of the hydrocarbons, of propane is, obviously, the flammability. The risk associated to the explosion possibility, related to hermetic compressors has been studied and solved in the small compressors for domestic appliances. The considerations about the hermeticity, the shell resistance to the explosion, are the same for commercial and air conditioning compressors. An additional precaution is the elimination of the starting relay and use for propane applications only PSC motor compressor. In case of real need of a High Starting Torque Compressor, the opportunity of a explosion proof enclosure for electrical components should be considered. A further difference with the domestic appliance is the amount of refrigerant charge; we move from tenth of grams to hundreds of grams. A careful risk assessment on each particular appliances must be performed. In case of refrigerant leakage, the permanence of the possible explosive mixture must be minimized.

CONCLUSIONS

In summary we can conclude that R290, as was demonstrated for R600a, has the best ecological and thermodynamic characteristic among the refrigerants suitable for air conditioning and commercial refrigeration use. The present hermetic compressors, designed for use with R502 and R22, while operating with propane show a strong benefit in terms of general reliability, due to the lower bearing loads and the lower thermal level. It has a positive influence on the risk associated to the use of flammable refrigerants. Even if in several International Standards the use of flammable refrigerants is allowed, we stress the importance of developing a risk assessment on each specific appliance.

References

- BS4435-95 Safety and environmental aspects in the design, construction and installation of refrigerating appliances and systems.

- DIN 7003-95 Kalteanlagen und Warmepumpen mit brennbaren Kaltemitteln der gruppe L3. Sicherheitstechnische Anforderungen.

- IEC 335-2-24 Draft-Amendment to cover the risk originated from the use of flammable refrigerants.

- prEN 378 Refrigerating systems and heat pumps - Safety and environmental requirements.

- IPCC Intergovernmental Panel on Climate Change - Maastricht 1994

- NIST - Standard Reference Data Base Refprop 4.0

- Zgliczynski M., Sansalvadore P. - Contribution to safety aspect discussion on isobutane compressor for domestic refrigeration - Embraco Aspera - Proceedings of 1994 International Compressor Engineering Conference - vol. II - Purdue 1994.